Sandhill Outdoor Skills Center
High School Independent Studies
Annual Report - 1999 / 2000

Greetings!

The 1999-2000 field season was the fifth year that the Skills Center offered an Independent Studies program to juniors and seniors from surrounding high schools. Twenty-nine students from 15 School Districts participated in this year's program offerings.

This program was created to 1). Promote an understanding and appreciation for our state's wildlife resources, and 2). Provide comprehensive learning experiences using scientific methodologies in the study of wildlife. This program addresses goal 3a in the Department's *Wildlife Education Plan*, enhancing the "…understanding of the role of wildlife management in maintaining healthy wildlife populations…", and the Outdoor Skills Center's Master Plan goal of "…increase public awareness about wildlife and wildlife management".

Students were selected on the basis of academic ability and interest in science. All students attended a training session before joining an inter-school district field team. Data collection occurred Monday through Friday, and students reported to Sandhill on their assigned dates throughout the study period. Following the field season, students reassembled at Sandhill to analyze the data they had obtained. Many students were required to prepare reports for school credit as a result of participation in this program.

The enclosed report summarized data collected in 1999-2000 by students involved in both the Wolf-Deer and Porcupine Ecology studies. The enclosed summary was prepared by Skills Center staff to demonstrate the quality of work and capabilities of these highly motivated high school students.

Many thanks both to **Whitetails Unlimited, Inc.**, and **Consolidated Papers Foundation, Inc.** for their financial support of the Wolf-Deer and Porcupine projects.

Porcupine Ecology Study
Progress Report
November 1999- April 2000

Participants:

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Introduction

Porcupines (*Erithizon dorsatum*) are endemic to forested regions of Wisconsin (Jackson 1961). This species is well known for the damage it causes to forest trees; foresters and woods-persons alike have killed porcupines - on sight - for generations (Jackson 1961, Krefting et al. 1962). Aside from humans, fishers (*Martes pennanti*) are the porcupine's only significant predator. Porcupines began colonizing central Wisconsin in the mid-1970's (Thiel unpubl.). The relatively recent reestablishment of porcupines to this region provides an opportunity to witness how the porcupine population has responded to this previously unutilized forest resource, and to determine what impacts porcupines have on forest trees.

Study Area: The present study is restricted to the southern half of Sandhill Wildlife Area located in southwestern Wood County, Wisconsin. It is owned and managed by the Wisconsin Department of Natural Resources, Bureau of Wildlife Management. This 9,150-acre wildlife area is surrounded by a nine-foot tall, deer-proof fence. Half of the area consists of wetland complexes. Upland forest and small grassland openings, the largest of which is 260 acres, occupy the remainder. Porcupines have been present on Sandhill since about 1978 (Thiel unpubl). Fishers are not present on Sandhill.

The objectives of the present study are to:

1) determine demographics (age, sex and numbers) and spatial organization of the porcupine population within Sandhill Wildlife Area, and,
2) assess the impacts of porcupine feeding on forest trees.

We hypothesize:

1) the relative age of porcupines can be determined by tooth wear and weight differences,
2) feeding damage to trees will not be appreciably greater than other sources of tree injury or death,
3) over-winter weight loss among porcupines is related to winter severity.

Methods

Population Parameters and Demographics: Between November and April each year, porcupines occupy wintering dens (Roze 1989). Searches were initiated in November at den sites where porcupines had been observed in previous winters. Additional porcupine dens were located throughout winter by following porcupine trails encountered in the snow while conducting other aspects of the study. Dens were considered occupied if a porcupine was seen, or if porcupine tracks led to or from the den. Occupancy was determined by repeated visits to the site.

At the end of the field season, minimum porcupine density was calculated for southern Sandhill according to the following formula:

$$D_{porcupine} = n_{captured} \, , \, Area_{total\ upland}$$

Porcupines captured outside of the study area were excluded from this calculation.

Porcupines were handled after injecting them with Telazol (Hale et al. 1994). Porcupines were captured by hand injecting them in dens, placing traps at den entrances, or surrounding the tree in which a porcupine was roosting with one-m-tall chicken wire, along which a trap was situated. All captured porcupines were weighed, sexed, ear-tagged, and color-coded with spray paint to aid in identification from a distance. A Passive Integrated Transponder (PIT) tag (AVID Friendchip, 14mm) was injected between the shoulder blades of each porcupine captured.

Turn-over Rate: Turn-over is the rate at which animals are replaced by other individuals. Turn-over is a function of emigration/ immigration, and birth/death. No barriers exist impeding movement of porcupines in our study area. Birth and death rates are difficult to assess, based on techniques used in the present study, but turn-over can be assessed by analyzing the relative recapture frequencies of porcupines ear-tagged in previous years. Turn-over was calculated by the following formula:

$$\textbf{Turn-over} = 1 - (n_{capyear+1} \div n_{capyear}) * 100$$

Where: n = number of porcupines
capyear = capture year
capyear+1 = the year following capture

Ear Tag Retention: Ear tag losses are known to have occurred within given field seasons and between seasons.

Ear tag retention rates were calculated as follows:

$$R = (n_1 + n_2 \ldots + n_w) \div (n_0 + n_1 \ldots + n_{w-1})$$

Where: R = estimated probability of ear tag retention
n_0 = number of animals tagged in original cohort
$n_{\#}$ = number of eartags remaining in animals x# years after original tagging
n_w = number of eartags remaining in animals at last year of study

Radio Telemetry: Transmitter packages were redesigned for field season 1999-2000. The package consisted of two alligator clips epoxied to the transmitter. The transmitter was clipped and glued to quills between the front shoulders. The packages were affixed to porcupines in mid-winter to allow better monitoring of the transmitter package at winter den sites. Radio telemetry was used to locate individuals once they left the winter den sites.

Aging: Porcupine premolar/molar rows were examined and tooth replacement and wear were recorded. The sequence of tooth replacement allows for accurate aging of juvenile (age <1 year), yearling (age 1-2 year) and adult (≥ 2 years) (Kochersberger 1950, Roze 1989). Adult tooth wear was subjectively ranked as “no wear”, “light”, “moderate”, or “heavy” based upon examination of porcupine skull specimens at the University of Wisconsin Zoological Museum.

Weight data were analyzed for potential as an age estimator. Data were separated by age class (juvenile, yearling, adult) based on tooth replacement. The range and mean were calculated for each data set. Preliminary weight limits for each age class were determined.

Louse Infestation: Each porcupine was examined for louse (*Trichodectes setosus*) infestation in four body areas (ventral: thoracic and inguinal; dorsal: nape and rump). Infestation was rated subjectively and recorded as follows: 0 - no lice present, 1 - light infestation, and 2 - heavy infestation. A lice index for two-month periods was calculated by:

$$\textbf{Lice Index} = \Sigma \left[\Sigma \textbf{ (infestation rate at sites 1,2,3,4)}_{\text{porkies 1 . . n}} \right]_{\text{n porkies}} \div n_{porkies} \div \textbf{4 body sites}$$

Weight Change: Winter weight loss was calculated for the 1996, 1997, 1998, and 1999 field seasons using individuals captured and recaptured between November and April of each field season. Average daily weight loss (W_{DL}) was calculated using the weight at capture and the weight at recapture.

$$W_{DL} = \textbf{(Weight Change}_{\text{initial capture – recapture}}\textbf{)} \div \textbf{No. Days Between Captures}$$

W_{DL} was compared with the corresponding Winter Severity Index (WSI) for the Central Forest region, Zone L (Sandhill DNR unpubl.). WSI is a relative measure using snow depth and temperature data for the period 1 December – 31 March.

“Summer” weight gain was calculated for 1997, 1998, and 1999 using individuals captured and recaptured between February and December of each calendar year. Average daily weight gain (W_{DG}) was calculated using the weight at capture and the weight at recapture.

$$W_{DG} = (\text{Weight Change}_{\text{fall wt} - \text{spring wt}}) \div \text{No. Days Between Captures}$$

Mortalities: Porcupines found dead within the study area were necropsied by the DNR pathology section in Madison.

Feeding Assessments: Students were assigned den sites and followed feeding trails in the snow around their assigned dens. For each visit, students recorded the date of the visit, the species and the diameter at breast-height (DBH) of each tree within one m of the trail. Tree data were separated into two catergories: "feed trees" which porcupines actively fed upon or "pass by trees" which showed no sign of current porcupine feeding. Students also recorded what region(s) of the tree feeding occurred on (trunk, limbs, or canopy) and attempted to estimate the percentage of debarking in each region.

Species preference is a measure of food selectivity by porcupines. Species preference (P_s) was calculated by dividing the number of times a porcupine fed on a species along feed trails (n_f) by the total number of times a porcupine trail passed within one m of the species (n_p).

$$P_s = n_f \div n_p$$

In April, a complete assessment of the extent of porcupine tree damage was gained by recording the species, DBH, and regions of debarking of all trees showing signs of porcupine use in the vicinity of den sites.

Students conducted random timber cruises of woodlots in the southern half of Sandhill to determine species composition, DBH, and basal areas. Damaged trees within each plot were evaluated for the source of damage (porcupines, disease, or weather). Feed trail data were compared with timber cruise data to evaluate the relative impact of porcupines on forest resources in Sandhill.

Results

Population Parameters and Demographics: Twenty-one porcupines were captured in 1999-2000, including two captured outside but within 100m of the south fence. Adults comprised 62% of overall captures, 47.6% were adult females (Table 1).

Nineteen porcupines were captured within the study area's 1947 acres of uplands. Minimum porcupine density was 0.98 porkies/100 ac (2.41 porkies/km^2). When porcupine density was recalculated to include animals known but never captured (n=4), density increased to 1.2 porkies/100ac (2.97 porkies/km^2).

Age-Sex Ratios: Tooth replacement and wear was used to determine age-classes among captured porcupines. Thirteen adults, two yearlings, and six juvenile porcupines captured in 1999-2000 were examined for tooth replacement and wear (Table 1). The sex ratio of adult captures was 77%? : 23%? . The adult sex ratio in 1998-99 and 1997-98 was 61%? : 39%? and 56%? : 44%? respectively.

Table 1. Age-sex distribution of porcupines captured in Sandhill Wildlife Area, WI, 1999-2000.

	Adult Female	Adult Male	Yearling Female	Yearling Male	Juvenile Female	Juvenile Male	Total
n Captured	10	3	0	2	3	3	21
% of Total Capture	48%	14%	0%	10%	14%	14%	100%

Weight data for 1998-99 and 1999-2000 were combined by age class for analysis. Weight ranges for the three age classes were: adults 11-20.25 lb (5.0–9.2 kg), yearlings 6.5-12 lb (3.0-5.5 kg), and juveniles 4-6.5 lb (1.8-3.0 kg) (Figure 1). The mean weight for adults was 15 lb (6.8 kg), while the mean for yearlings and juveniles were 9 lb (4.1 kg) and 5 lb (2.3 kg) respectively.

Figure 1. Weight of all porcupines aged by tooth wear analysis in Sandhill Wildlife Area, WI, 1998-2000.

Age-weight analysis was used to determine probable age class ratios of porcupines caught in 1996-97 and 1997-98 to identify any changes in age-class ratios between years. Adults were defined as animals weighing >11 lbs, yearlings as 6-11 lbs, and juveniles as <6 lbs. Based on age-weights, adults comprised from 62 to 77 percent of the population; yearlings comprised 10 to 29 percent; juveniles from 0 to 28 percent (Table 2) annually.

Turn-over Rate: Four years of capture data were analyzed to calculate a turn-over rate of 65 percent.

Radio Telemetry: Adult female #15 and adult male #62 were fitted with radio transmitters. The female was located twice, each time in her winter den. The radio slipped off within five days. The radio slipped off of the male while he was in the holding pen awaiting release following processing.

Table 2. Age ratios of porcupines in Sandhill Wildlife Area, 1996 - 2000.

		Juvenile	Yearling	Adult
1996-97[1]	N	1	2	10
	%	8	15	77
1997-98[1]	n	0	6	15
	%	0	29	71
1998-99	n	2	5	13
	%	10	25	65
1999-2000	n	6	2	13
	%	28	10	62

[1] based on age-weight analysis

Louse Infestation: Heaviest louse infestation was observed in March and April. November and December had the lightest louse loading (Table 3). Juvenile and yearling porcupines exhibited a higher rate of infestation than their adult counterparts.

Table 3. Porcupine lice loading index by time period in southern Sandhill Wildlife Area, WI, 1999 - 2000.

Time Period	No. Porcupines Sampled	Lice Index
November/December	4	0.13
January/February	13	0.98
March/April	4	1.06

Weight Fluctuation: On average, porcupines in southern Sandhill lost 8.6 g/day during winter 1999-2000, 13.66 g/day in winter 1998-99, 12.95 g/day in winter 1997-98, and 20.2 g/day in winter 1996-97 (Table 4).

Table 4. Porcupine winter weight loss in Sandhill Wildlife Area, WI, 1996 - 2000.

	n Porcupines Sampled	0 Daily Weight Loss (g/day)	n Porcupine Days	WSI
1996-97	6	20.20	381	208
1997-98	4	12.95	349	29
1998-99	4	13.66	319	25
1999-2000	1	8.6	105	19

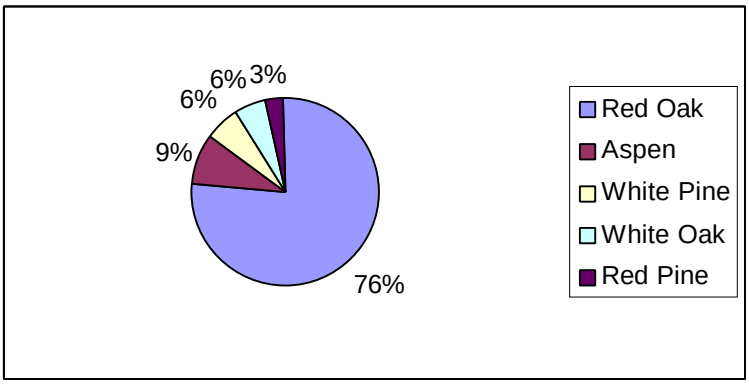
During the summer months of 1999-2000, an adult female gained an average of 8.8 g/day. An adult male gained an average of 2.9 g/day during summer 1998. Three adult females gained an average of 9.5 g/day during summer 1997.

Mortalities: No mortalities are known to have occurred within Sandhill Wildlife Area during 1999-2000.

Feeding Assessments: Seventy-six percent of trees fed upon by porcupines were red oak (*Quercus rubra*). Aspens (*Populus* spp) composed 9 percent of the trees fed upon while white pine (*Pinus strobus*) and white oak (*Quercus alba*) composed 6 percent each. Three percent of porcupine feed trees were red pine (*Pinus resinosa*) (Figure 2). The four most common species in southern Sandhill were red oak, aspen, black oak, and white oak (Table 5).

Species preference calculations showed that porcupines never passed by a white pine, a relatively uncommon species in Sandhill. Porcupines passed within one m without feeding on 100 percent of paper birch (*Betula papyrifera*), 99 percent of aspen, 91 percent of white oak, 77 percent of red oak, and 50 percent of red pine.

Figure 2. Tree species used by porcupines for winter food in Sandhill Wildlife Area, 1999-2000.



Porcupines selected larger oaks (0 DBH 34 cm) and pines (0 DBH >45 cm) to feed from, but selected mid-sized aspens (0 DBH 19 cm). Feeding topology differed by species. In oaks and pines, most feeding took place in the limb and canopy regions in contrast to aspens, where most feeding took place in the trunk and limb regions.

Table 5. Comparison of forest composition with porcupine food selection by species and DBH for two study seasons, 1996-97 and 1999-2000.

Species	Study Year	Timber Cruise		Feed Trails			
		Rank	0 DBH (cm)	Pass-by		Feed	
				Rank	0 DBH (cm)	Rank	0 DBH (cm)
Red Oak	1999-2000	1	28	2	14	1	34
	1996-97	1	31	1	22	2	38
Aspen spp	1999-2000	2	20	1	5	2	19
	1996-97	2	16	3	22	1	18
Black Oak	1999-2000	3	34	--	--	--	--
	1996-97	--	--	--	22	--	--
White Oak	1999-2000	4	22	3	10	3	>45
	1996-97	3	23	2	22	3	39
Pin Oak	1999-2000	5	21	--	--	--	--
	1996-97	--	--	--	--	--	--
Paper Birch	1999-2000	6	17	4	7	--	--
	1996-97	4	14	--	--	--	--
White Pine	1999-2000	7	25	--	--	3	>45
	1996-97	--	--	--	--	4	60
Red Pine	1999-2000	8	23	5	37	5	>45
	1996-97	--	39	--	36	--	50

Tree damage assessments revealed that disease is the major cause of tree injury and death in the study area. Overall, disease caused 88 percent of tree damage observed in timber cruise plots. Weather, including wind and lightening, caused 12 percent of observed damage. No porcupine damage was observed in timber cruise sample plots.

Table 6. Damaged tree assessment, by species and cause, in southern Sandhill Wildlife Area, 1999-2000.

	Tree Species				
	Red Oak	Aspen spp	Black Oak	White Oak	White Pine
Feed Tree Rank	1	2	--	3	3
Total number trees (n)	200	140	92	52	6
Number damaged trees (n_d)	82	6	21	4	1
Number damaged by porcupines (n_p)	0	0	0	0	0
Number damaged by disease	77	0	21	1	1
Number damaged by weather	5	6	0	3	0
% damage caused by porcupines ($n_p \div n_d * 100$)	0	0	0	0	0
Porcupine damage in perspective ($n_p \div n * 100$)	0	0	0	0	0

Discussion

Porcupines selected hollowed trees, rock outcroppings, and culverts as winter dens. The highest den density was located on North Bluff in 2 escarpments. Rock outcroppings were preferred over hollow tree dens in other studies (Roze 1989, Krefting et al. 1962).

Turn-over in a population is caused by movements of individuals into and out of the study area, and by variations in birth and death rates. On 18 January 2000, movement of porcupines in and out of the study area was documented for the first time. An adult male originally captured on 9 December 1999 was observed using a den outside of Sandhill, about 0.5 mi south of the capture location.

Reliable identification of individuals is imperative to calculate turn-over rates accurately. Ear tag loss has been documented within study years and between years. Paint remnants, ear scars, and nipple counts were used with limited confidence to identify animals suspected of losing an ear tag. "Mistaken identity" may contribute to the calculated 65% turn-over rate. We hope that PIT tags will eliminate the problems caused by lost ear tags and allow us to calculate turn-over rates and other population statistics more accurately.

We have experimented with a new radio design in each of the past two field seasons. We are currently trying to design a radio pack that porcupines will be unable to remove, and which will not harm the wearer. Due to porcupine anatomy, this proves difficult. Nevertheless, the ability to locate individuals will greatly aid our ability to search for causes in high turn-over rates (natural movements, harassment-based movements, mortality), and to determine spacial relationships of porcupines living on Sandhill.

Porcupine tooth replacement patterns allowed us to immediately separate young animals into the juvenile or yearling classes. Tooth wear may allow us to subdivide adults into more specific age classes, but more data is needed, preferably a continual wear record for each individual we study. Tooth wear is currently used to age whitetail deer (*Odocoileus virginianus*) and other large herbivores. Tooth wear differs with diet and nutrition (Wilson 1996), but this problem should be overcome by developing an aging technique with porcupines local to Sandhill.

Body mass is a good indicator of age in medium and large sized mammals because it changes so much during early development stages (Wilson 1996). During the last two field seasons, a relatively clear weight division between juvenile, yearling, and adult porcupines existed. The weight definitions may change with more data in future years, but we are confident these modifications will be slight.

Roze (1989) proposed that nursing offspring pick up lice directly from their mother or from her shed fur in the spring. Neither explanation fits our observation of highest infestation in March and April, about the time animals are leaving their winter dens. We hypothesize that transmission of lice is likely a direct result of den sharing or switching during the winter months, as porcupines are primarily solitary animals during the rest of the year.

Winter weight losses in 1997-98, 1998-99, and 1999-2000 were very similar, as were WSI ratings for each winter. The relatively small difference in average daily weight loss between the more severe winter of 1996-97 and the mild winters of 1997-2000 indicates that the WSI, developed for measuring impacts on deer, may not adequately measure stress factors for porcupines. WSI is based on temperature and snow depth data, the stress factors for whitetail deer. We suspect temperature regimes are more critical determinants of weight loss among porcupines.

A 30% difference in summer weight gains was noted between summer 1997 and 1998 while 1999 weight gains were similar to 1997 rates. The calculations for 1997 and 1999 included only female porcupines while 1998 included only male porcupines. The sample size for calculations was very small for all three years. Therefore, it is not clear if the differences are due to weather, sample size, or sex differences. An effort must be made to capture and recapture more individuals within the summer sampling time frame to make further hypotheses.

No porcupine damage was observed in random timber cruise plots. During the feeding assessment study of 1996-97, a few random plots overlapped with winter den sites; there was no overlap in 1999-2000. This finding indicates that porcupines have little impact on forest resources as a whole in Sandhill; their feeding is limited to the area surrounding the winter den sites. Some extensive feeding damage was observed on trees near traditional winter dens, but no tree mortalities caused by porcupines were observed.

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Deer - Wolf Ecology Studies

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Introduction

Sandhill Wildlife Area in southwestern Wood County, Wisconsin, a 9,150 acre facility operated by the Wisconsin Department of Natural Resources, is entirely surrounded by a 9-foot tall, deer-proof fence. Studies on deer (*Odocoileus virginianus*) herd age-sex composition, harvest impacts, and deer census techniques have been conducted on Sandhill since 1962. Much of the previous work has focused on aspects of human harvesting of deer.

Humans hunt deer for sport in highly regulated seasons. Wolves are predators of white-tailed deer (Mech and Frenzel 1971, Kolonosky 1972, Thompson 1952). Some deer hunters express concern that wolf predation may affect their success in hunting white-tails (McRae 1994, Pryse 1997).

Wolves (*Canis lupus*) have been absent from the Sandhill region since circa 1900, but recolonized the area beginning in 1992 (Thiel 1993). An adult male wolf escaped into Sandhill in May 1995 and has resided there since (Boehm 1997, WDNR 1997).

Until recently, canid predation (limited to coyotes [*Canis latrans*]< 1995) on deer in Sandhill was not considered appreciable. Assessing the impacts of predation requires that, "the number of wolves in an area, the number of prey animals in the same area, and the rate at which the wolves remove the prey" be known (Kolenosky 1972). Such quantitative data is difficult to measure. Further, factors such as snow depth and competition at kill sites with scavengers (mainly coyotes and corvids) influence kill rates (Fuller 1991, Paquette 1992).

The purpose of this study is to:
(1) determine the spatial partitioning of bucks and does,
(2) calculate survivorship trends among deer, and
(3) ascertain the influence of both human harvest and wolf predation on deer.

Methods

Weather. Data were maintained on daily temperatures, snowfall, and snow depth by students and DNR personnel at Sandhill Headquarters.

Wildlife Populations. Annual coyote, beaver (*Castor canadensis*) and deer population statistics were gleaned from files maintained at Sandhill headquarters. Annual beaver colony counts provide the basis for long-term beaver population indices. Age-sex data are maintained on deer harvested by humans and deer dying natural deaths. Herd size and productivity are provided by irregular helicopter censuses and fall trail counts, and summer deer observations and placental scars from harvested does, respectively.

Wolf Study. Students entered the facility almost daily, Monday through Friday, working in teams of 1 to 4 people and walked, snowshoed, or drove along roads searching for wolf tracks. When tracks were encountered, students attempted to trail the wolves to locate prey remains. Students recorded information on distances traveled daily, and distances traveled on wolf trails.

Scats encountered on trails were teased apart to identify prey remains. Tracks adjacent to scats or the diameter of scats were used to distinguish between coyote and wolf droppings (Weaver and Fritts 1979). Kill-sites were inspected to determine the species, age and sex, and condition of prey at time of death. Vital materials such as jaws used in aging deer, were removed and given to DNR personnel for age analyses (Anon. n.d.). Samples of bone marrow, taken from the femur bone, were collected to determine health condition (Mech and DelGiudice 1985).

Deer Study. Deer were captured in a Grange Model box trap baited with hay. Captured deer were subdued by opening one trap door over which a net was suspended and pinning them to the ground. Radio transmitter collars were placed on selected deer while subdued. All deer captured were sexed and ear-tagged. Attempts were made to estimate age by inspecting wear on lower incisor teeth, and by assessing relative body size.

Deer were released at capture sites, and locations were obtained once weekly by determining direction of radio signals from pre-selected locations, recording bearings, and plotting triangulations on maps, as described by Mech (1983). Locations with large "errors of polygon" were rejected and not used in determining home range size. Deer locations were plotted on maps drawn from aerial photographs, and home ranges were determined by using the minimum area method (Mohr 1947 *in* Nelson 1981).

Impact of Wolf Predation. Age of predator-killed deer was compared to 1999 hunter-killed age statistics, and the age structure of non-harvested deer recovered in Sandhill between 1963 and 1994. Age stratification of the non-harvested deer cohort was assumed to represent herd age spread and was used to determine if humans and predators (wolves and coyotes) were selecting different age groups.

Utilization rates were determined by estimating the percent of each carcass that had been consumed by the wolf or coyotes, and returning to carcasses periodically to determine if each had been subsequently utilized. Consumption was calculated by determining the age and sex of deer when possible, and utilizing weight data on fall hunter-killed deer at Sandhill (Table 1) (DNR files), converting dressed weight to whole weight using the formula:

Whole Weight = 4.15 + 1.2487 x dressed weight

used by Kolenosky (1972). Daily consumption rates were calculated by taking this figure and multiplying it by the percent utilization of each carcass, and dividing by the number of days wolf trails were followed:

[3 (Whole Weight) x % utilization]) # days on wolf trails

Weights were expressed in kg.

Table 1. Mean dressed weights (kg) of Sandhill deer harvested in November 1999 (Sandhill DNR files).

Sex	Age						
	Fawn	**1**2	**2**2	**3**2	**4**2	**5**2	**6**2
Buck	26.9	43.1	51.8	62.5	71.9	-	-
Doe	26.2	37.7	44.6	45	49.5	46.7	52.2

The impact of wolf predation on the deer herd can be determined by calculating the number of deer preyed on by wolves using the following formula:

 # Deer Taken by Wolves Annually =

3_{Season} **[kg/Wolf/Day x # Days x % Deer in scats x # wolves**
) 0 Deer Wt (kg)]

where season is divided by monthly periods, and the mean deer weight is 54 kg.

Scavenging of deer gut piles and unretrieved deer killed by hunters following the deer hunting season is another potential food source for wolves and coyotes. Hunters were asked to report the location of any dead deer they encountered while hunting. These were inspected by DNR staff immediately following the hunting season to gain an impression of the volume of food available to canids following the November hunt. Age and sex were determined, and weights were calculated for each dead deer. Students inspected these carcasses at irregular intervals, noting incidences of scavenging by species, and amount. Consumption rates were calculated in the same manner as discussed above.

Results

Weather Data:

Work was conducted intermittently between 3 January and 22 February 2000,as snow conditions allowed. A low of -15^{o}F was recorded on 22 January, and a high of 57^{o}F was recorded on 22 February. Table 2 describes snowfall and mean depth, in inches by month during winter 1999-2000.

Table 2. Sandhill snowfall data, winter 1999-2000.

Month	December	January	February	March
Total Snowfall:	**5.25**	**8.6**	**6.5**	**4**
0 **depth:**	**3.1**	**5**	**6.2**	**4**

Continuous snow cover extended over a 71-day period from 3 January through 14 March. The number of days with at least 15 inches of snow on the ground was 0; the number of days with temperatures below 0^0F was 19; and the *Winter Severity Index* for winter 1999-2000 was 19.

1999-2000 Predator and Prey Population Estimates:
The post-season deer herd was estimated at 427 deer (28 deer/mi^2) in Sandhill. Beaver reached a 20 -year low in 2000 with only 5 active colonies counted. Four to six coyotes were estimated to use portions of Sandhill during winter 1999-2000. Only a single adult male wolf (named "Twisted Knee") was found within Sandhill. This wolf has been present on Sandhill since 1995 and is estimated to be 6 years old.

***Trailing Data*:**
Table 3 yields comparative data from 1996 through 2000. Eighteen students from 10 school districts participated in the 30-day study. The total miles walked and driven, and the average daily miles walked and driven was similar to the first 3 winters of study despite poor tracking conditions caused by the mild winter weather (Table 3).

Table 3. Effort in searching for wolf sign, 1996-2000.

		Miles (km) traveled by Students					
Year	**# Days**	**Total Walked**	**Total Driven**	***0*** **Walked Daily**	***0*** **Driven Daily**	**Walked & Driven Total**	***0*** **Daily**
1996	25	251.8 (402.7)	0	10.1* (16.1)	0	251.8 (402.7)	10.1* (16.1)
1997	35	202.4 (323.8)	63.7 (101.9)	5.8 (9.2)	6.4 (10.1)	266.1 (425.7)	7.6 (12.2)
1998	23	90.4 (144.7)	99.0 (158.4)	3.9 (6.2)	4.4 (6.9)	189.5 (303.0)	8.2 (13.2)
1999	19	52.8 (84.6)	15.75 (25.2)	2.8 (4.5)	15.75 (25.2)	68.6 (109.75)	3.6 (5.8)
2000	30	166.35 (266.16)	42.8 (68.5)	5.5 (9.5)	8.6 (13.8)	209.2 (336.6)	6.9 (10.2)

*This data represents 2, 2-person crews daily. Therefore, each 2-person crew averaged 5.0 mi/day.

Wolf Tracking Data:
Tracking data on wolf trails is presented in Table 4. Daily wolf trail encounter rates have varied considerably in the 5 years (range 37 to 76 percent). This winter was the second lowest encounter rate observed. Two deer kills were found in 32 miles of tracking for an average of 16 mi (25.4 km) between kills, the second highest rate observed in the 5 years.

Table 4. Wolf tracking data, 1996-2000.

Year	# Days Trailed	Daily Encounter Rate (%)	Total Miles (km) Tracked	***0*** **Miles (km) Tracked/Day**	Longest Daily Session	# Deer Kills Found	Miles/Kill (km/kill)
1996	19	76	28.8 (45.2)	1.5 (2.3)	4.6 (7.4)	1	28.8 (46.0)
1997	23	66	44.2 (70.7)	2.3 (3.7)	5.2 (8.3)	7	6.3 (10.1)

1998	14	61	26.3 (42.1)	1.8 (2.9)	5.2 (8.3)	4	6.6 (10.6)
1999	19	37	9.4 (15)	0.5 (0.8)	1.5 (2.4)	2	4.7 (7.5)
2000	15	50	31.75 (51)	2.2 (3.4)	5 (8)	2	15.9 (25.4)

Scats: Twelve winter wolf scats contained 83 percent deer, 8 percent Lagomorph, and 8 percent other remains. Eight winter coyote scats contained 89 percent deer and 11 percent Lagomorph remains. This was the highest recorded incidence of deer in coyote scats in the 5-year study.

Kill Statistics: Remains of two predator-killed deer were located in winter 2000 (Tables 5 and 6). The first kill was found on a wolf trail; the other was reported by a citizen (Table 6). In addition, the wolf killed and consumed 1 cottontail (*Sylvilagus floridanus*) and 1 fox squirrel (*Sciurus niger*).

Table 5. Cause of death of deer, by month, discovered January - March, 2000.

Mortality Type	January	February	March
Snow depth (in)	5	6.2	4
Wolf	1	0	0
Coyote	0	1	0
Starvation	0	0	0

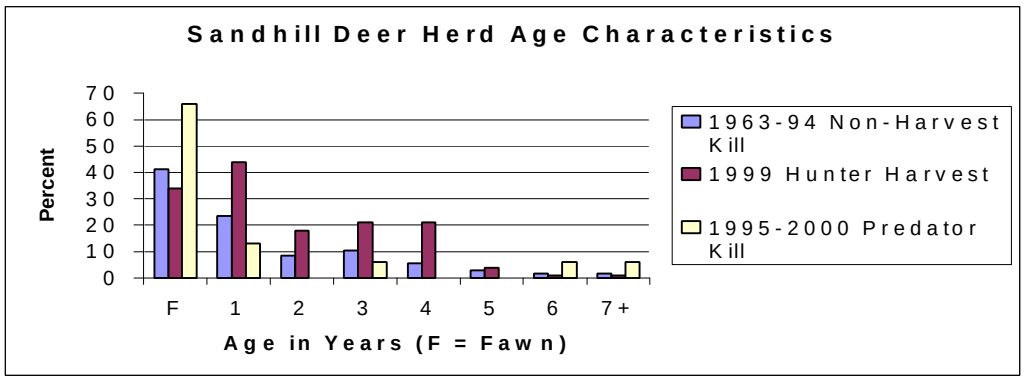
Table 6. Age, sex and condition of predator-killed deer located in 2000.

Map Loc	Date of Kill	Cause of Death	Sex	Age	Percent Consumed	Marrow Condition	Scavenged?
1	1-5-00	Wolf	M	1.5	90	Creamy white	No
2	2-7-2000	Coyote	M	F	45	White-Good	Wolf scavenged 45 percent

[1]unknown

Age Selection: Fifteen known-age predator kills since 1995 are compared to the 1999 hunter-harvested deer, and non-harvest kills discovered in Sandhill between 1963 and 1994 in Figure 1. In the present study, predators and hunters select different age groups of deer: predators selected *young and old* and hunters selected *prime-aged* (ages 1-4 years) deer.

Figure 1. Differences in age selection of deer in Sandhill Wildlife Area.



Kill and Utilization Rates, and Condition of Dead Deer: Snow depths were shallow throughout the winter of 1999-2000. The observed utilization rate was 90 percent on the single kill attributable to the wolf. Bone marrow condition was good in the two predator-killed deer. Despite the small sample size (Table 6), this suggests that deer were not nutritionally stressed this winter.

Deer Telemetry:

Capture Efforts, 2000: Table 7 yields data on trapnights (TN) during the study. Eleven deer were captured in 18 TN, for a success of 1 deer / 1.6 TN. Doe 79, captured and radioed in 1998, was recaptured this winter. Total trapnight effort varied from 32 in 1997, 44 in 1998, 38 in 1999, and 18 in 2000 (Tables 8 & 9). Trapnights/capture ranged from 0.125 in 1997, 0.113 in 1998, 0.23 in 1999, and 0.61 in 2000. The increased success in 2000 may be attributable to greater familiarity/efficiency of staff, and an increased number of fawns captured in 1999 and 2000 (6 in 1999 and 5 in 2000 vs 1 each in 1997 and 1998).

Table 7. Deer capture success, Sandhill Wildlife Area, Winter 2000

Month	Trapnights	Captures	Recaptures	Snapped Traps
January	**12**	**7**	**0**	**0**
February	**6**	**3**	**1**	**0**
Totals	**18**	**10**	**1**	**0**

Productivity Trends: Summer 1999 deer observations reflected a fawn/ doe ratio of 0.47, down significantly from 0.72 in summer 1998. Two of the five radioed deer produced 3 fawns. One fawn disappeared in mid August, for a net reproductive rate of 0.4 among our radioed does. Placental scar count data taken from the uteri of does harvested in fall 1999 were unreliable.

Survivorship Trends: Since this program began in January 1997, 4498 deer-days (12.3 deer-years) of telemetry survivorship data has been accumulated on individual deer. One deer was killed by a wolf 55 days after capture/collaring. Radio-collared doe 042 was shot during the 1999 season. Several hunters reported seeing and/or taking shots at other radioed deer without success. Previous years' hunter stigma against shooting radioed deer may have biased survivorship trends of radioed deer. Another bias involves sample size: only 2 bucks and 10 does have been monitored (Table 8). Nonetheless, yearly survivorship of bucks is calculated at 49 percent, does, 81 percent, and both buck and does combined, 72 percent.

Table 8. Radioed deer data summaries, Sandhill Wildlife Area, Winter 1997-2000.

Capture Date	Sex	Age	Ear-tag Number	No Locs.	Fate	Home Range (acres)	Min. Days of Survival
01-22-97	M	>1.5	273*	84	Continued monitoring	708	996
01-29-98	F	>2.5	078	66	Continued Monitoring	427	745
01-30-98	F	>1.5	096	50	Continued monitoring	530	764
02-11-98	F	>1.5	079**	70	Continued monitoring	193	732
02-13-98	F	>1.5	099	44	Continued monitoring	568	730
01-07-00	F	>1.5	026	7	Continued monitoring	73	68
01-19-00	F	>1.5	043	9	Continued monitoring	247	54
02-09-00	F	F	039	8	Continued monitoring	127	36
02-09-00	F	F	044	8	Continued monitoring	115	36
02-10-00	F	F	034	8	Continued monitoring	100	35
01-23-97	M	7.5	272	14	Killed by timber wolf 3-19-97	N/a	55
01-14-99	M	A	047	6	Shot off property 11-17-99	N/a	N/a
02-09-99	F	A	042	33	Shot on property 11-14-99	300	247

***recaptured 01/07/99 ** recaptured 02/07/00**

Home Range Size: Table 8 provides data on radioed deer, including home range calculations. The size of 5 adult does' home ranges ranged from 193 to 568 acres, and averaged 403.6 acres. Buck 273's home range was 708 acres.

Table 9. Non-radioed deer captures and fates, Sandhill Wildlife Area, Winter 1997-2000.

Date of Capture	Sex	Age	Ear-tag Number	Information	Min. Days of Survival
01-28-97	M	1.5	271		
02-06-97	F	F	270	Found starved 04-04-97	57
02-10-98	M	F	097	Shot by hunter *outside* SH, 11-21-98	284
01-05-99	M	F	046		
01-05-99	M	F	050		
01-06-99	F	F	041		
01-06-99	M	F	049		
01-07-99	F	F	045		
02-09-99	F	F	048		
01-19-00	M	F	038		
01-26-00	F	A	030		
01-26-00	F	A	040		

Ratios of Radioed to Non-radioed Deer within SE Study Area: Ten radioed deer (9 does: 1 buck) spend a significant portion of their time within the southeastern-most square mile of Sandhill (Map 2). Ratios of non-collared to collared deer observed within this area may provide a crude estimate of deer densities on Sandhill. While not absolutely accurate, such figures can be used to gauge the effectiveness of more refined census techniques used on Sandhill. Observations made from 1 March through 30 June (Table 10) yield a ratio of 10 non-collared deer to 1collared deer. Multiplying this ratio and the 10 collared deer, 100 deer were estimated to exist within the square mile study area, much higher than the over-wintering density of 29 deer/mi^2 calculated in winter 1999-2000. The 1998-99 estimate was much closer: 22.5 deer estimated vs 28 deer/mi^2 calculated to exist in Sandhill.

Table 10. Observations of non-collared/collared deer in SE mi^2 in Sandhill.

		Non-Collared Deer Observations					Collared Deer			
Year	No. Days	Does	Fawns	Bucks	Unk	Total	Does	Bucks	Total	Ratio Uncollared: collared
1999 - 2000	275	52	26	7	45	130	13	0	13	10:1

Impact of Wolf Predation on Sandhill Deer Herd

Consumption Rate of Wolf: Based on the known number and ages of kills and scavenging of prey remains located in 2000, a consumption rate of 5 kg of meat/day was calculated for the Sandhill wolf during the 30-day study period (Table 11). This is slightly higher than previous winter rates recorded in this study. Table 11 also compares the consumption rate in the present study with a pack of eight wolves studied in Ontario by Kolenosky (1972). Consumption rates in the present study are higher than reported for a pack of 8 wolves studied by Kolenosky (1972) in Ontario, and by Mech (1977) in northeastern Minnesota (Table 11).

Fall Scavenging Potential - Harvested Deer Gut Piles and Unretrieved Kills: Hunters harvested 133 deer in November 1999. This represents 1577 kg of gut piles (112 kg or 246 pounds per square mile); potential food for wolves and coyotes. In addition, 6 of 13 unretrieved deer (328.5 kg) were inspected by students. Scavenging, which occurred at all 6 sites, was broken down as follows: wolf – 43 percent (142.5 kg); coyotes – 50 percent (165.7 kg); avies (primarily corvids) – 6 percent (20.3 kg).

Table 11. Consumption rate of wolves in Sandhill and in Ontario (Kolenosky 1972).

Location	Number of Wolves	Year	Deer Density deer/mi^2 (deer/km^2)	Ave. mi (km) per kill	Ave. days per kill	Days/Kill/Wolf	Food/Wolf/Day (kg)
Ontario	8	1968-69	8.6 (5.4)	8.8 (14.2)	2.2	17.7	2.8
Sandhill	1	1996-97	24.7 (15.4)	6.3 (10.1)	4.5	4.5	4.4
Sandhill	3	1997-98	25.0 (15.6)	6.6 (10.5)	3.5	10.5	4.2
Sandhill	1	1998-99	25.0 (15.6)	13.0 (21)	7.0	7.0	2.8
Sandhill	1	1999-2000	29.0 (18.1)		7.5	7.5	5.0

Table 12 breaks down the calculation of deer taken on Sandhill by season. In the previous biological year (1 June 1999 to 31 May 2000) the wolf consumed the equivalent of 22.6 deer. In 1997-98, the calculated take of deer by wolves was 37, and in 1998-99, the wolf consumed an estimated 22.7 deer on Sandhill.

Adjusted Impact of Wolf Presence on Deer Herd: Assuming the amount of food the wolf scavenged (142.5 kg, or the equivalent of 2.6 deer at 54 kg each) compensated for a live deer he would have "removed" from the herd, the adjusted take in 1999-2000 would have been 20 deer. This does not include any compensation for scavenging on gut piles.

Discussion

For the third winter in a row the 1999-2000 winter was mild, and deer experienced little or no winter-related stress. All wolf sign was attributable to the lone male wolf who entered the facility in May 1995.

This single wolf consumed an estimated 23 deer on Sandhill in 1999-2000 (Table 12), not compensating for the scavenging of 2.6 deer following the fall deer hunt. This is comparable to the number he removed in 1998-99. The adjusted total (20 deer), which compensates for scavenging on unretrieved hunter-kills, is close to the 4-year average of

23.5 deer/wolf/year (Table 13). The average number of deer harvested annually by hunters is 77 deer (Table 13). We believe the presence of wolves on Sandhill represents an *additive* source of mortality for deer. However, humans normally harvest fewer deer annually from the Sandhill herd than are recruited through reproduction (recruitment is:(350 X 1.3) - 350, or 100 fawns). The fact that deer herd size has not changed in a 3-year period indicates that human harvest (77/year) and wolf predation (23/year) has a stabilizing effect on the herd (removal of 100 deer/year)under mild winter conditions.

Table 12. Calculated annual "take" of deer by wolves on Sandhill, March, 1999 – February 2000.

Period	kg/Wolf/Day	# Days	% Deer in Scats	# Wolves	Total Wt (kg) Consumed	Total Weight) 0 Deer Wt	Total Deer
Mar – May	5.0	92	0.37	1	170.2	54	3.15
June – Aug	5.0	92	0.37	1	170.2	54	3.15
Sep – Nov	5.0	91	0.37	1	505	54	9.4
Dec - Feb	5	90	0.83	1	373	54	6.9
Year 1999-2000 Sum				1	1218.4		22.6

Table 13. Deer population and harvest trends, Sandhill Wildlife Area, 1991- 99.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave
Hunter Harvest	55	146	49	56	63	54	76	62	133	77
Wolf						14	37	23	20	23.5
Total						68	113	85	153	104

We recommend the following:
(1) Continue to monitor wolf predation and assess consumption rates of wolves on Sandhill,
(2) monitor radioed deer to determine *annual* home range sizes, and maintain contact with an average of 6 adult deer per year in the SE study area,
(3) determine fawn recruitment of radioed does in Sandhill,
(4) place ear-tag transmitters on 2-4 fawns in winter 2000 - 01, and
(5) obtain at least 25 deer locations per season to increase accuracy of home range sizes.

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